

Riparian Monitoring of Wadeable Streams Protocol Implementation Plan for the Park Units in the Southern Colorado Plateau Network

Standard Operating Procedure (SOP) # 9

Data Analysis and Reporting

Version SCPN_Riparian_20180930

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP is adopted from the Northern Colorado Plateau Network's SOP #14 Preparations for the field season and equipment needed, Version 1.02 (September 2016) in Weissinger, R., D. Witwicki, H. Thomas, A. Wight, K. Lund, and M. Van Grinsven. 2018. Riparian monitoring of wadeable streams protocol for park units in the Northern Colorado Plateau Network: Version 1.05. Natural Resource Report NPS/NCPN/NRR—2018/1636. National Park Service, Fort Collins, Colorado

This SOP provides an overview of analysis and reporting procedures. After raw data from the field season are quality checked, they are then summarized to the reach level. Additional QAQC is performed comparing these data to previously collected data to catch misidentified species and values that represent unlikely amounts of change between years. Once data quality issues are resolved, analyses can be conducted. Two general types of analyses are performed: 1) summary reporting of the most recent monitoring observations (summary reports and annual briefs), and 2) comprehensive assessments of the long term data set (assessment of the overall sampling design, evaluation of status and trends, and correlations with other vital signs).

1.0 Data Summary

The sampling unit for wadeable streams analyses is the reach, and sub-samples recorded on transects are scaled to this level (see Figure 1). Summary queries in Access can be used for many of the vegetation summaries. Vegetation and geomorphology data may be integrated at the transect level, but are ultimately summarized to the reach level. Hydrology data are summarized from data taken throughout the water year. There may be cases when reaches are evaluated separately and data are summarized to the transect level, but this SOP will only focus on summary and analysis at the reach level.

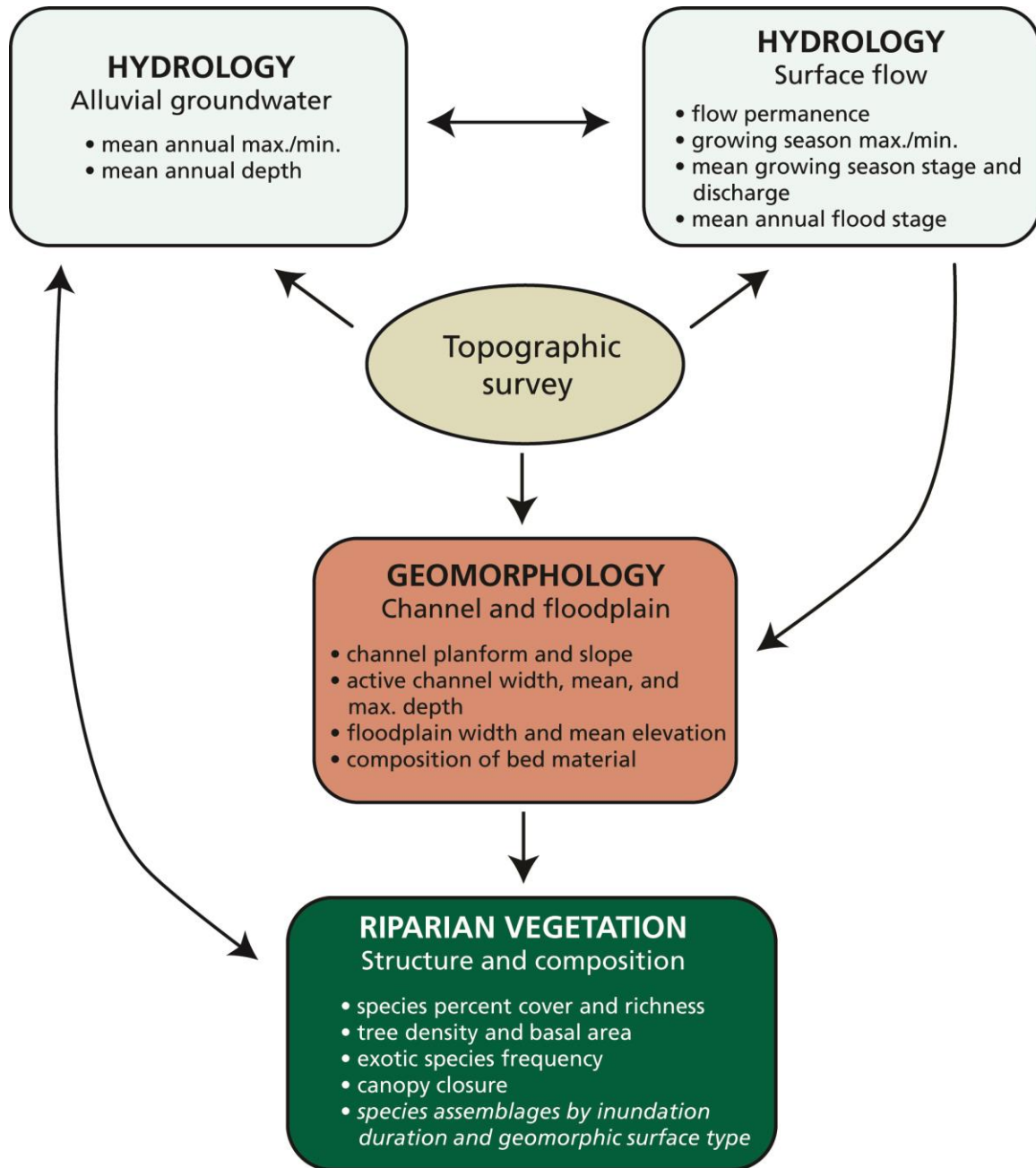


Figure 1. Conceptual model illustrating relationships among measurements for wadeable stream vital signs and their metrics. Geomorphic metrics of channel planform and slope and the vegetation metric for large trees are established at the reach scale. These are integrated with the remaining metrics, which are collected at the transect scale.

Vegetation Summaries

Richness

Species richness is the number of unique species encountered. For each reach, calculate richness of all species, nonnative species, species by life form (e.g., tree, shrub, etc.), and species by wetland status group. Richness of dominant species can be compiled from point-intercept data. It is important that species richness is derived using the same methods and area sampled for all years and reaches in an analysis. Otherwise, rarefaction methods will need to be used if the number of sub-samples changes within or among monitoring plots (e.g., Krebs 1989, Ludwig and Reynolds 1988). In addition, a species list for the reach is assembled using all vegetation measures.

Percent Cover

Percent cover is calculated for each species, life form, wetland status group, ground cover attribute, and disturbance using point-intercept data from transects. It is derived by summing the number of points where each species, etc. is hit, and dividing by the total number of point-intercept readings across all transects, times 100 (eq. 1, Table 1). Canopy closure is the average of all densiometer readings across a reach expressed as a percent (eq. 1, Table 1).

Exotic frequency

Exotic frequency is derived from the number of detections of each exotic species in the 1-m² quadrats, and reported as the percent of detections.

Density

Density is derived from trees in the 5-m belt. It is the number of trees counted divided by the total area of the belt transects, scaled to stems per ha (eq. 2, Table 1). This measure is calculated for each species by size class.

Basal Area

Basal area is the cross-sectional area of trees divided by the total area of the 5-m belt transects, scaled to m² per ha. Basal area and density are correlated and should always be considered together when reviewing data summaries of each (eq. 3, Table 1).

Census of large diameter trees

The tree census summary includes the total number of trees and the distribution of DBH and crown health classes.

Geomorphology Summaries

After total station survey post processing, relevant geomorphic surfaces are delineated by elevation or abrupt surface breaks on each transect. The data can then be integrated with other measurements or summarized to the reach-level.

Channel morphology

The mean active channel width and depth in meters (eq. 4, Table 1) and the channel slope in meters per kilometer are calculated for the reach using data from the geomorphology

survey transects. The distribution of particle sizes in the channel bed is derived from the pebble count, and the diameter of streambed particles in the 50th and 84th percentiles (d50 and d84) is determined.

Flood plain morphology

The mean flood plain width and elevation in meters is calculated for the reach using data from the geomorphology survey transects. The delineation of the flood plain will be estimated until enough hydrologic data are collected to determine this.

Arroyo Metrics

In parks where the stream channel occupies a well-defined arroyo (e.g., CHCU), metrics including arroyo top width, average and maximum depths, and width/depth ratios will be calculated for each arroyo transect, following methods in Gellis (2002). Mean values may be summarized by reach.

Hydrology Summaries

Summarize hydrologic data by the calendar year of January 1 to December 31 and for the growing season of March 1 to October 31. From the final approved data, calculate a daily mean for each day that has 90% or more observations (87 out of a possible 96 for 15-minute data), starting at midnight and including observations up to 23:59.

For each well, present a time series of all depth to water (to 0.01 m) or discharge (to 0.1 m³ per second) data for the summary period and a time series of daily mean data for the summary period. For depth to water, reverse the y-axis so that larger values are shown at the bottom of the y-axis and the time series provides a depth profile. Include a table of all manual water depth measurements (to 0.01 m) including the date and time (to minute) each measurement was taken. Include a table of all gaps in the datasets (missing data).

Summary statistics are sensitive to the amount and type of data that are missing from the period of interest. Missing data can occur due to equipment failure, staff turnover, ice, flooding, siltation or other causes. The following metrics may be calculated when 90% or more of the daily means are available. Even then, caution must be used to investigate whether missing data are biased, such as those caused by sensor malfunction during a flood event or those that occur during a period in which the spring peak might have passed. If a metric cannot be calculated, document why.

Table 1 presents a summary of metrics that should be presented for each stream type and summary period, with additional details on calculating metrics provided below. Metrics were chosen to reflect changes in both the amount and timing of flow/stage over time. Discharge summaries can only be calculated after an acceptable rating curve is in place.

Table 1. Summary of stage and discharge metrics calculated for each stream type and summary period. See the text for additional information on how each metric is calculated and presented.

Metric	Perennial	Intermittent	Ephemeral	Annual	Growing Season	Monthly
Median	X	X	X	X	X	X
Minimum	X	X	X	X	X	X
Maximum daily	X	X	X	X	X	X
10 th quantile	X	X	X	X		
30 th quantile	X	X	X	X		
70 th quantile	X	X	X	X		
90 th quantile	X	X	X	X		
Absolute maximum	X	X	X	X		
Spring peak	X	X	X	X		
Center of volume	X	X	X	X		
Total volume	X	X	X	X		
Channel overflow	X	X	X	X		
Flow permanence		X	X	X		
End of flow		X	X	X		
Beginning of flow		X	X	X		

Calculate the following summary statistics for annual, growing season, and monthly datasets for each well for depth to water (to 0.01 m) or discharge (to 0.1 m³ per second):

- Minimum daily mean $\pm$ one standard deviation, date, day of year from Jan. 1 (DOY)
- Median daily mean $\pm$ one standard deviation, date, DOY
- Maximum daily mean $\pm$ one standard deviation, date, DOY

Calculate the following summary statistics for annual daily mean datasets:

- 10th quantile daily mean $\pm$ one standard deviation
- 30th quantile daily mean $\pm$ one standard deviation
- 70th quantile daily mean $\pm$ one standard deviation
- 90th quantile daily mean $\pm$ one standard deviation

Present the following summary statistics for annual 15-minute datasets:

- Absolute maximum stage or discharge

For instream well or gage data, additional surface water summaries include:

- Spring peak - date and DOY when spring peak flow occurs, defined as the highest daily mean in the relatively smooth hydrograph corresponding to snowmelt run-off
- Center of volume - date and DOY on which half of annual mean volume has passed through the system

- Total annual volume – calculated as the sum of (daily mean * 60 seconds * 60 minutes * 24 hours) in m³ to 4 significant digits
- Channel overflow - using the 15-minute instream well data: number of events during which surface water overflowed the channel, duration of overflow (to 0.25 hours), date of each event. The specific elevation that determines overflow is derived from the contemporary channel cross-section data for the well transect at each reach.

For intermittent and ephemeral instream wells:

- Flow permanence - annual and growing season % of days with flowing surface water, defined as daily mean water elevation (to 0.01 m) greater than or equal to the channel thalweg elevation defined by the contemporary channel cross-section survey
- End of flow - date and DOY when continuous surface flow ceases in spring or summer, defined as >1 day with daily mean water elevation (to 0.01 m) less than the channel thalweg elevation defined by the contemporary channel cross-section survey
- Beginning of flow - date and DOY when continuous surface flow resumes in fall, winter or early spring, defined as >1 day with daily mean water elevation (to 0.01 m) greater than the channel thalweg elevation defined by the contemporary channel cross-section survey
- Longest disturbance-free period – Greatest number of days bracketed by floods and/or dry periods

Integrated Summaries

Vegetation data are integrated with the geomorphology survey transects to derive mesic to xeric plant cover by surface elevation and species richness and percent cover by geomorphic surface elevation. Vegetation data are integrated with the hydrology data to derive species assemblages by inundation duration and frequency.

Inundation duration of the floodplain (% of growing season) will be determined using geomorphology surveys and hydrologic data, and will be more meaningful as additional floods are recorded. Inundation frequency of the floodplain (return frequency in years) requires multiple years of hydrologic data in addition to a survey of the flood plain.

Table 1. Formula for deriving reach-level measures.

Percent Cover

$$PC = (h / n) * 100 \quad (1)$$

where PC = percent cover
h = the number of points where each species, ground cover attribute, life form, or overstory is hit
n = the total number of points per reach

Tree Density

$$D = 10,000 * t / \left(\sum_{i=1}^q z_i \right) * w \quad (2)$$

where D = density of trees in stems/ha
t = the number of trees in the 5-m belt
z_i = length of riparian transect i
q = total number of riparian transects
w = width of belt transect in m

Basal area

$$BA = \left(\sum_{i=1}^y [(DBH_i / [2 * 100])^2 * \pi] \right) / \left[\left(\sum_{i=1}^q z_i \right) * w / 10000 \right] \quad (3)$$

where BA = basal area in m²/ha
DBH_i = diameter at breast height in cm for tree i in the 5-m belt
y = the total number of trees with DBH measures
π = 3.142
z_i = length of riparian transect i in m
q = total number of riparian transects
w = width of belt transect in m

Mean (channel width, etc.*)

$$M = \left(\sum_{i=1}^v c_i \right) / v \quad (4)$$

where M = mean channel width in m
c_i = channel width in m for transect i in a reach
v = the total number of transects in the reach

* channel width shown in this example, but this formula is also used for channel depth, flood plain width and elevation, annual and growing season stream stage, annual and growing season stream discharge, annual flood stage, and depth to ground water.

2.0 Data Quality Assessment

Before data analysis and reporting, reach-level data should be additionally evaluated for reasonable levels of change based on historical conditions at each reach. For instance, a measure may appear to be valid based on the database domain, but represent an unreasonable (and unlikely) change in reach conditions since the last field visit. Summarized attributes should be compared between years, and all suspect values (large increases or decreases) should be flagged and resolved before the data are analyzed. In addition, data should be evaluated for the omission of historically dominant species or the appearance of dominant species not detected in previous years. New occurrences of a species should be compared with the park-level species list and species-range limits.

Suspect measures or species should be evaluated by field crew members and by field verification if possible. Any corrections made to the database should be recorded in the QAQC log. Suspect data that are not resolved should also be flagged in the QAQC log so that it can be excluded from analyses, if appropriate. Suspect data that cannot be resolved in the office should be brought to the attention of the field crew at the next monitoring visit so that they may eventually be resolved.

3.0 Summary Reports

Summary Reports

The primary objectives of the summary report are to 1) document monitoring activities for the period of record, 2) summarize data and describe the current condition of resources, and 3) provide information to park managers in a timely manner that increases data utility and communication. A separate report is completed for each SCPN park unit with wadeable streams monitoring. Existing SCPN reports should be consulted for formatting.

4.0 Comprehensive Assessments

Comprehensive analyses and reports are completed periodically on the long term data set. Comprehensive reports should be structured like typical scientific manuscripts (introduction, methods, results, discussion, and literature cited sections) and may include any of the analyses described in this section.

Sampling-Design Variance Assessment

The sampling design for riparian monitoring at each stream is documented in a separate report that outlines specific sampling objectives and in Appendix A. Periodic checking of the assumptions of the sampling design affords timely opportunities to invoke enhancements to meet the original monitoring and sampling objectives. Sampling designs are evaluated by calculating variance and power for trend, and assessments are recommended every 5-7 years.

Variance estimates are derived from all years of monitoring data, not just observations from the current field season. Where necessary, alternative survey designs are evaluated to determine appropriate enhancements, such as an increase in sample size or more frequent visits to established reaches, to achieve the original sampling objective. Power-for-trend is evaluated with alternative numbers of panels, sample sizes, and re-visit schemes. A trend may be reported as a yearly rate or a rate over a set number of years. This conversion is outlined for increasing (eq. 5, Table 2) and decreasing (eq. 6, Table 2) rates of trend. Results are then used to determine which survey designs best meet the original sampling objectives.

Preliminary assessments of riparian monitoring data suggest that inference to the stream level may be difficult due to the low number of reaches sampled on each stream, the relatively short length of each stream within the sampling frame, and the need for consistent data before and after flood events. If survey designs are abandoned in the future, this particular variance assessment would not be needed, but an assessment of the overall sampling design would continue in some form.

Table 2. Formula for converting a yearly rate of trend to a rate of trend over a set number of years.

Conversion for rate of trend

$$I = e^{rt} \quad (5)$$

$$D = 1 - e^{-rt} \quad (6)$$

where;

I = % increase over t years

D = % decrease over t years

r = the yearly rate of increase or decrease

t = the total time period of increase or decrease

Status and Trend Assessments

The underlying motivation for using survey designs to monitor wadeable streams is the ability to make inferences to a finite, target population. Alternatively, model-based designs and assessments rely on modeled relationships, and thus tend to have inherent assumptions, and in some cases, limitations in terms of the scope of inference. However, model-based assessments may be useful to help explain reasons for trends observed in survey-design efforts, and information from other vital signs monitoring (e.g., climate, air quality, land use, land condition) or other sources may prove critical to interpreting observed wadeable stream trends. Bayesian methods may detect trends earlier than frequentist methods and should be developed over time.

Status and trend analyses are performed after at least 5 years of monitoring data are collected. Data are analyzed for the period of record (long-term trends), and for any period where 1) a change is expected to have occurred due to a known impact at or upstream of the site (e.g., a major flood event) or 2) a change is apparent after a graphical inspection of the data record. When significant trends are detected, reasons for these trends should be evaluated by literature reviews, comparison with similar data sets, and additional assessments using ancillary information. When unidirectional trends are not detected, correlations may help us understand system drivers.

Frequentist Methods

Frequentist trend assessments of complex survey designs are performed using a mixed-effects model (Larsen et al. 1995). Reach-scale measures are used in the model and evaluated on the basis of time. The output from this model is a measure of the intercept and slope, the significance of the slope and intercept being different from zero, and measures of the variance and covariance of the regression parameters. A significant slope indicates a significant trend at the alpha level used to assess significance or below.

Status is the condition of the attribute and is derived in two ways. If the trend slope is not significantly different from zero, mean and variance of status is simply the mean and variance of all measures of the attribute up to the current time period. If the slope is significant, then status is the solution of the regression model for the latest time period of the data used to generate the trend line (eq. 7 in Table 3). Variance measures of mean status are derived from the covariance matrix of the regression coefficients (eq. 8 in Table 3).

Table 3. Formula for deriving status and trend estimates.

Mean Status From a Trend Line

$$ST_t = b_0 + b_1 * t \quad (7)$$

where;

ST_t = estimate of mean status at time = t

b_0 = the estimated intercept parameter

b_1 = the estimated slope parameter

t = the most recent time period of the data (in the same units used to generate b_0 and b_1)

Standard Error of Status

$$SeST_t = \sqrt{(\sigma_{b_0}^2 + 2t \sigma_{b_0b_1} + \sigma_{b_1}^2 t^2)} \quad (8)$$

where;

$SeST_t$ = the standard error of the mean-status estimate at time = t

$\sigma_{b_0}^2$ = the variance of the intercept parameter

$\sigma_{b_0b_1}$ = the covariance of the regression parameters

$\sigma_{b_1}^2$ = the variance of the slope parameter

t = the most recent time period of the data

Model-Based Methods

Model-selection procedures consider a range of potential factors influencing directional change in resource conditions. Even if a significant trend occurs as a function of time, the relationship between other explanatory variables and riparian measures should be evaluated to determine potential ‘causal’ factors of trends. These other explanatory variables can include biophysical features of the reaches as well as measures from other vital signs monitoring (e.g., climatic conditions).

Model selection methods (Burnham and Anderson 1998) evaluate the explanatory power of different models of trends in riparian measures. Multiple models are considered, each with different combinations of independent variables and interaction terms. All models should be based on hypothesized, ecologically meaningful relationships. Adjusted AIC (Akaike’s Information Criterion) values generated with a mixed-effects model are used to determine the best predictive model as well as the importance of independent variables.

The primary model in this model-selection procedure is the response of interest vs. time (see frequentist methods above). Alternative models can be based on measures of climate, air quality, land use, and land condition, as well as other measures that may be considered important. When evaluating other variables, they are either included in an interaction with time or time is replaced with the variable.

The result of the model-selection procedure is the selection of the model (i.e., set of independent variables) which best predicts the trend of the response variable. This, in turn, aids in explaining reasons for the observed trend. For instance, if alternative models with one or more driver attributes (e.g., drought days) accounted for more variance than just using time, trends may be attributed to these attributes in a correlational relationship, but not necessarily a causal relationship. If alternatives to time account for less variance, other avenues of investigation should be considered to explain reasons for observed trends.

Bayesian Methods

Bayesian methods for trend assessment identify the probability of different slope-parameter values (Gelman et al. 2000, Wade 2000) given the observed data. This differs from frequentist methods which calculate the probability of observing data given a specific value for a parameter, such as the null hypothesis. Assessing the probability of different slope values is potentially important for various reasons. First, sampling designs are largely based on a few key features. The minimum detectable trend at a reasonable power level for many of the other responses will likely be much higher. Estimating the probability of slope values may be the best way to provide insight into trends for these attributes. Second, even for the key features around which sampling designs were based, Bayesian methods may reveal the potential of declining trends before rejecting the null hypothesis that the regression slope equals 0 with conventional statistics.

Bayesian methods use a likelihood distribution generated from the sample data that provides the probability of observing the data for every possible parameter value. Combining this with a prior distribution produces a posterior distribution which is used to make inference about parameters. The prior distribution reflects previous knowledge about the distribution of parameters. In the absence of such knowledge, a non-informative distribution can be used, which essentially is a uniform distribution across the range of the likelihood distribution. In subsequent analyses, the posterior distribution of previous assessments is used as the prior distribution. The posterior distribution allows assessments of the probability of user-selected parameter values. The probability of various increasing and decreasing slopes should be evaluated based on the posterior distribution and the consequences of not alerting management of a potential trend. The result of this assessment is the derivation of the probability of different levels of decline/increase. Even though conventional statistics may not reveal a significant trend, relatively high probabilities (e.g., ≥ 0.70) of trends with a Bayesian method may warrant special attention.

Correlations

There will be instances where a monitored attribute fails to exhibit a trend (i.e., a direction change), but instead may have periods of decline followed by recovery. In other words, natural variation may be more evident than a precipitous decline or increase, and it may mirror the variation in a key driver attribute. Discerning this variation and reasons for it can involve many complex procedures. As a first step, however, correlational methods can provide useful insight and are relatively simple.

For attributes that fluctuate between declines and increases, correlations with climate, air quality, land cover/use, land condition, and other potential drivers should be considered. Strong correlations between a response and driver may be sufficient to understand reasons for the observed variation over time (e.g., strong correlation between shrub cover and annual precipitation).

Another type of correlation assessment is path analysis (Lindquist 2000). This method accounts for the inter-correlated structure among factors by decomposing correlations to direct and indirect effects. For instance, changes in grass cover in a shrub-steppe system may be influenced by shrub cover alone or by climate alone or by the influence of climate on shrub cover. A path analysis would decompose the effects of climate and of shrubs on grass cover, while considering the combined influence of climate and shrubs. The result of a path analysis is the indication of the strength of direct and indirect factors on a response, thus providing insight into reasons for the observed changes in a response. Path analysis is based on correlation values and the simultaneous solution of structural equations. Simple examples of the construction and use of path analysis are provided in Lindquist (2000) and Van Bruggen and Arneson (1986); details of path analysis are provided in Pugese et al. (2003).

5.0 References

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